Reconstruction of the 22 May 2007 Magnetic Cloud:

How Much Can We Trust the Flux-Rope Geometry of CMEs?

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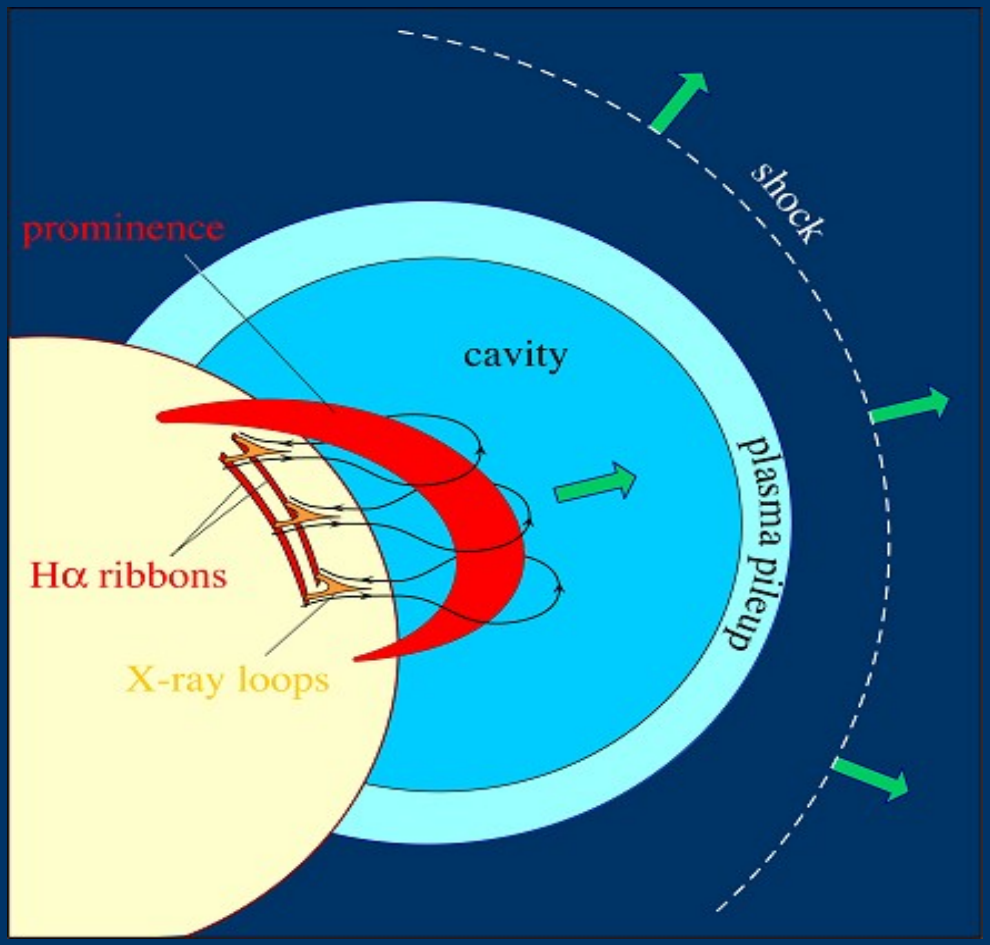
Liu et al., ApJ Lett., 2008

Brief introduction



Forbes, 2000

- The flux rope exists before eruption - flux-rope driven CMEs (e.g., Chen 1996, Lin & Forbes 2000);
- The flux rope is produced by magnetic reconnection during eruption (e.g., Mikic & Linker 1994);
- None of CME theories have been fully tested yet.

Brief introduction

- Goldstein (1983) proposed a force-free flux-rope model for magnetic clouds (MCs), and various flux-rope models have been developed since then;
- An isolated plasmoid model (Vandas et al. 1993a, b) also gives good fit of MCs.

How much can we trust the flux rope structure of CMEs?

How do we verify the flux-rope structure?

- Multi-spacecraft reconstruction:

1, reconstruct the flux rope using data from only one spacecraft;

2, reproduce the data at another spacecraft with the reconstructed structure.

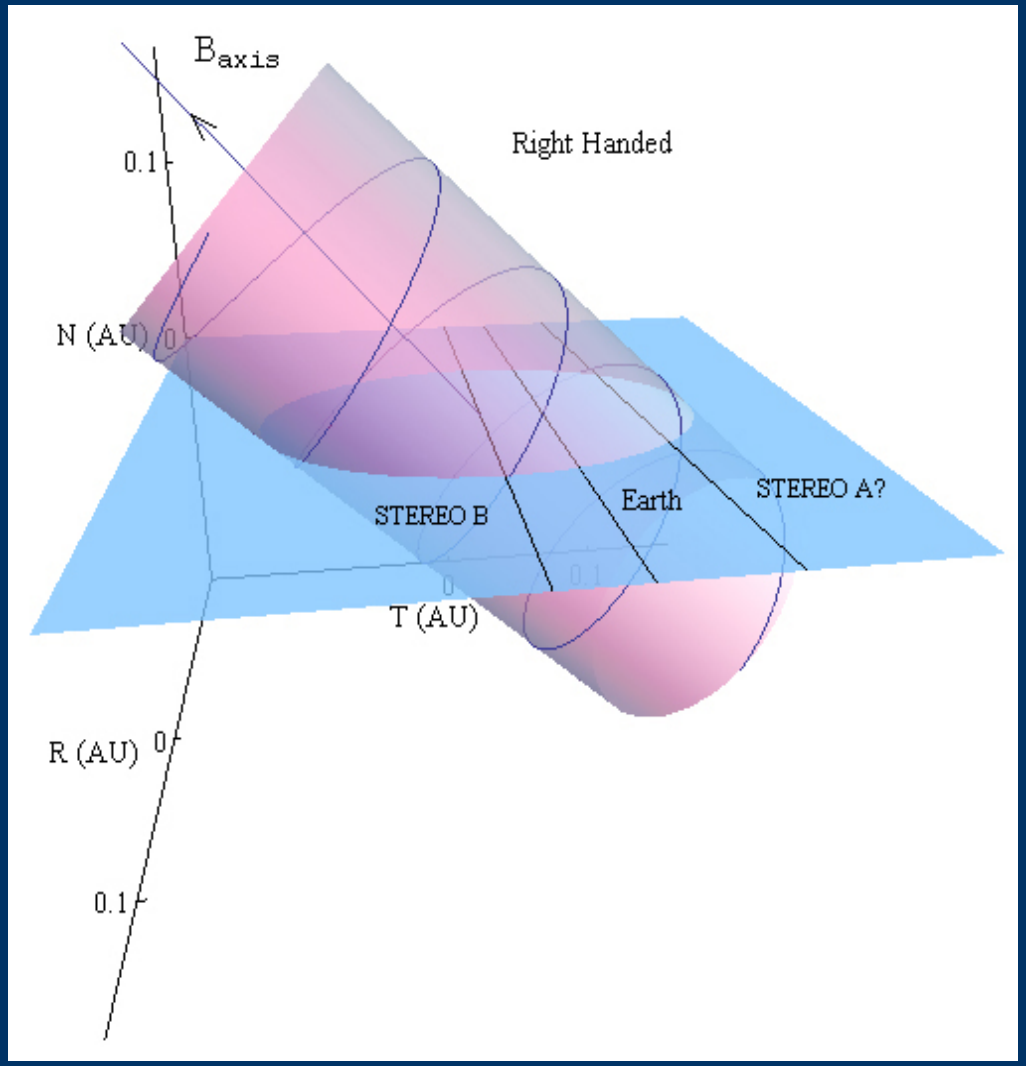
- Requirement on the separation of the two spacecraft:

1, at a small separation, the two spacecraft observe essentially the same structure, not interesting (e.g., Wind and ACE).

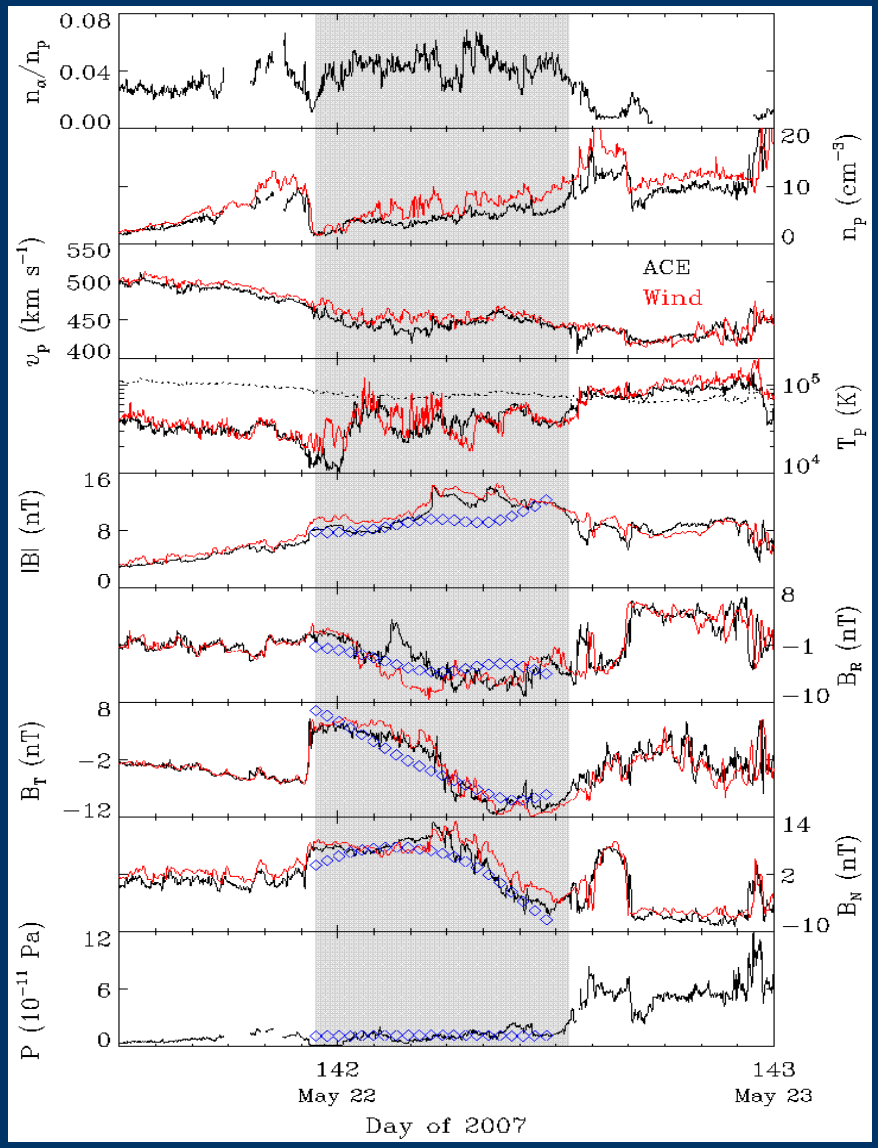
2, if too widely separated, distortion by the ambient solar wind would be very different; also limited by the calculation scheme.

The 22 May 2007 magnetic cloud

- The MC is passing these spacecraft along the radial direction from the Sun;
- Separation between STEREO B and Earth, 3 degrees, or 0.06 AU;
- Separation between Earth and STEREO A, 6 degrees, or 0.11 AU;
- Provide a great



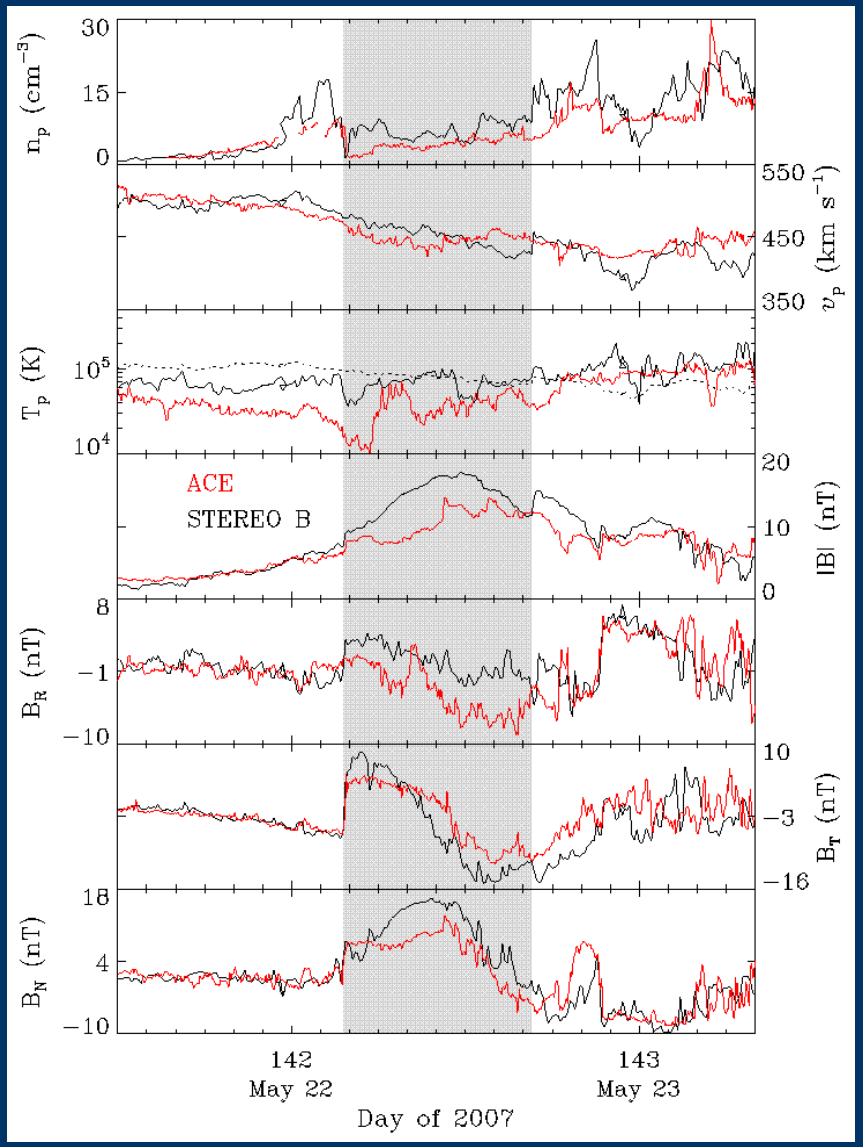
Data at ACE / Wind



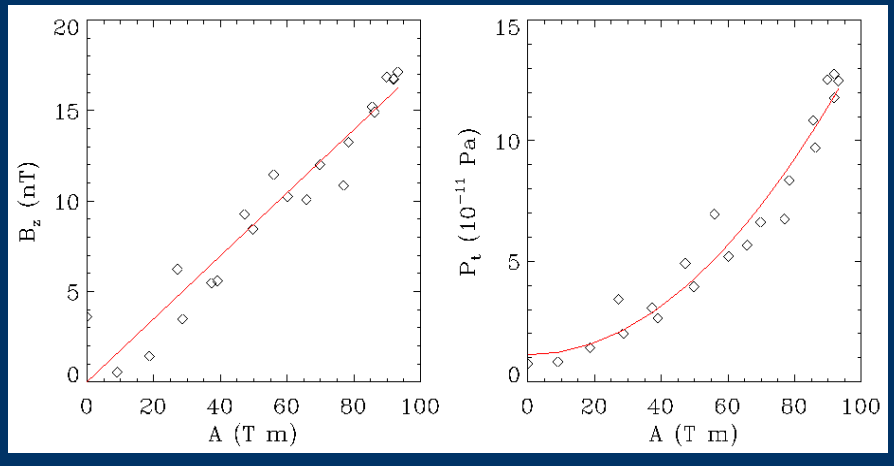
- Wind and ACE observe almost the same structure due to small separation;
- Comparison between ACE and Wind data could not give constraints on the MC structure.

Data at STEREO B and ACE

- ACE data are shifted by 5.3 hr;
- STEREO B data are apparently different from ACE data, so STEREO B and ACE are well separated;
- Upstream fields at ACE and STEREO B are similar, so the two spacecraft are not too much separated;
- Could give strong

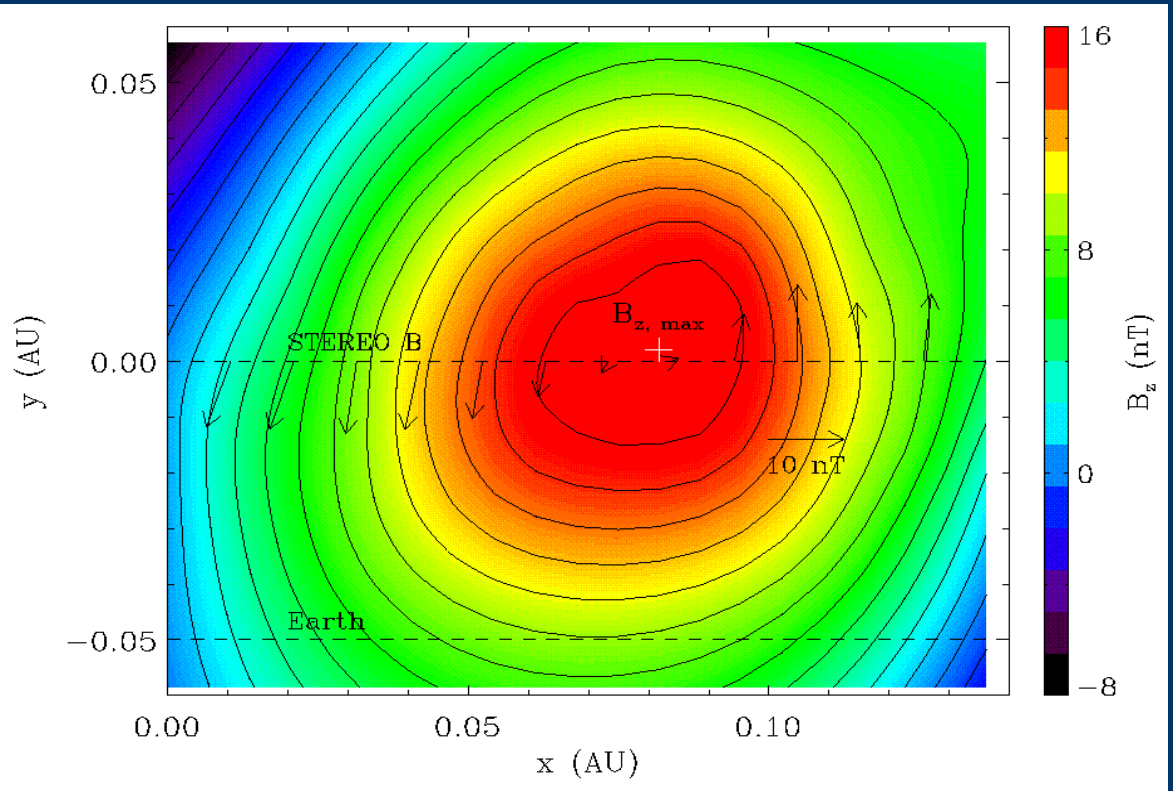


How do we play the trick?



Grad-Shafranov (GS) reconstruction (Hu 2002).

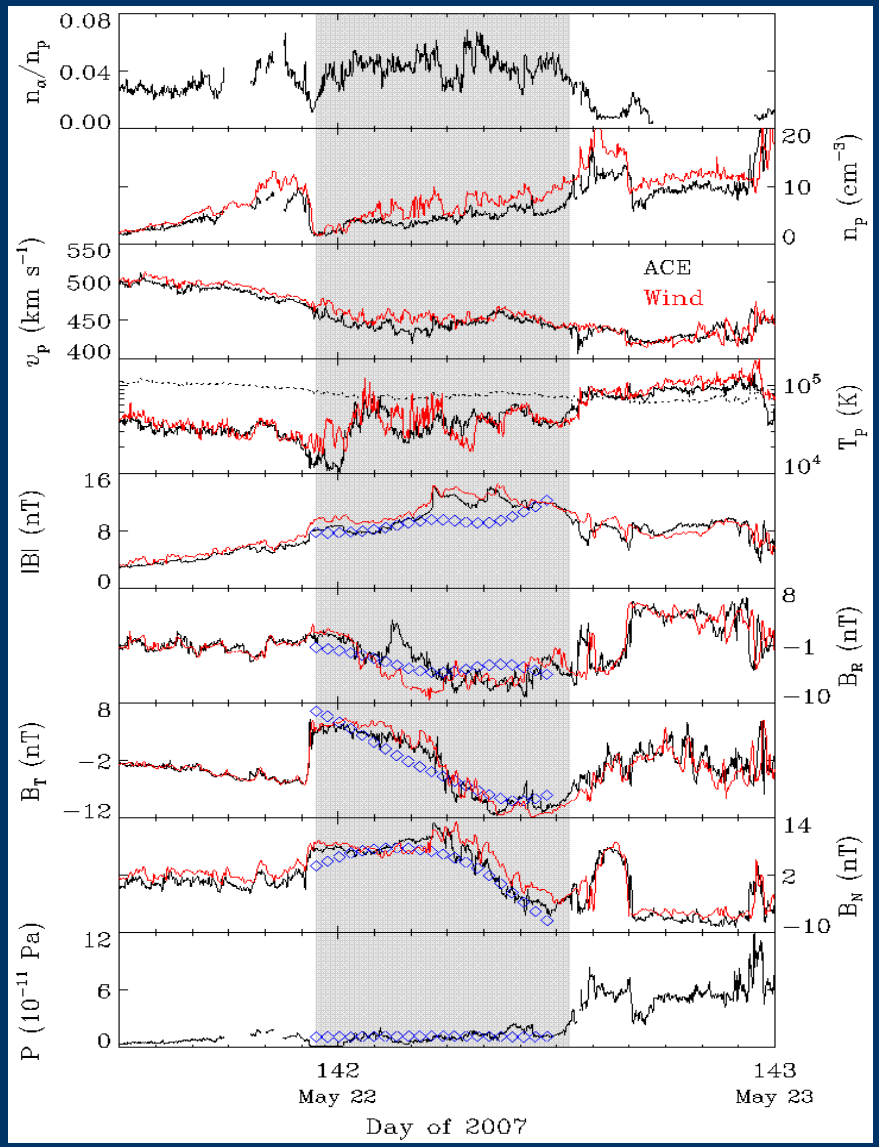
$$\frac{\partial^2 A}{\partial x^2}+\frac{\partial^2 A}{\partial y^2}=-\mu_0\frac{d}{dA}\left(p+\frac{B_z^2}{2\mu_0}\right).$$



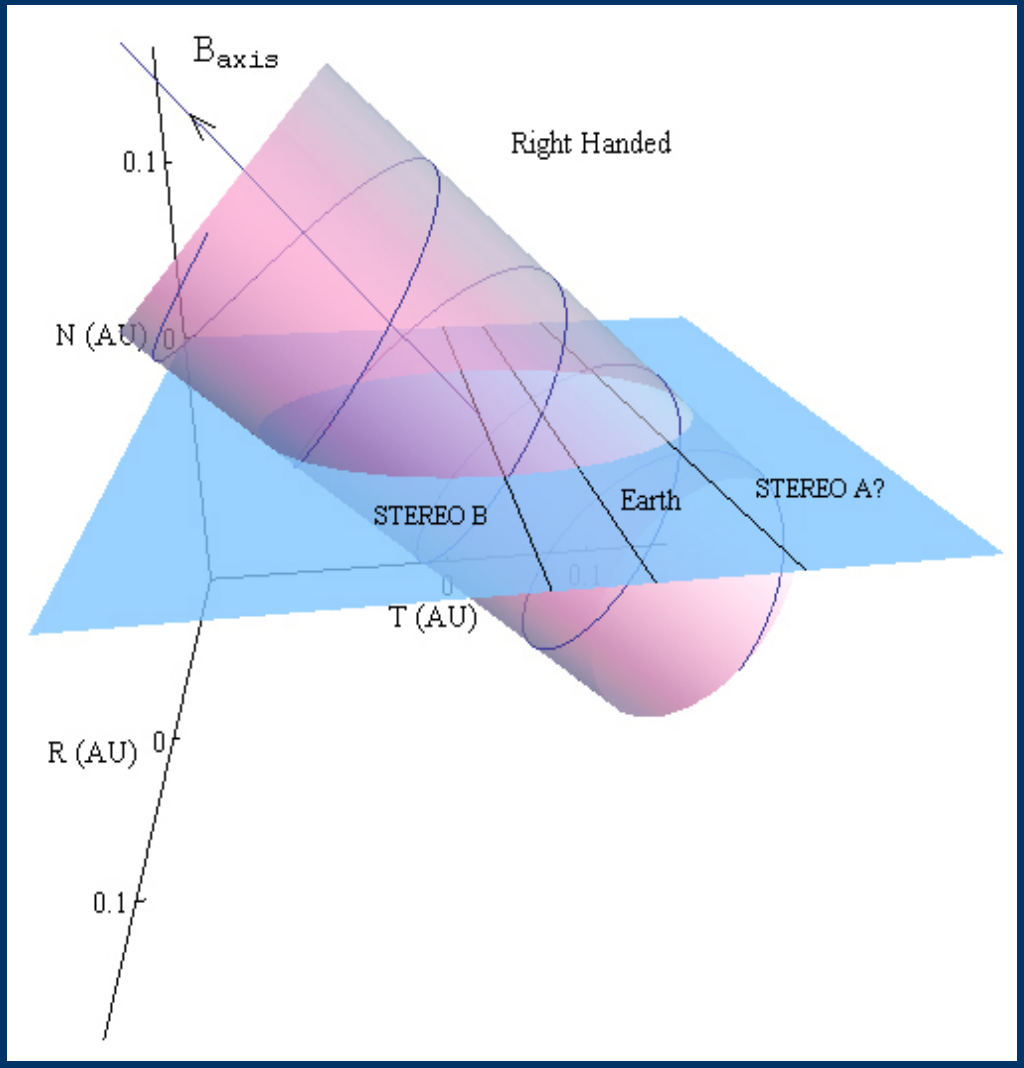
- The right-hand side is a function of *A* alone!!!
- Get the right-hand side from STEREO B data only, and it should be the same along any crossings;
- The equation can then be solved, resulting in the cross section;
- Get model output along

Data-Model comparison at ACE / Wind

- Model output generally agrees with the fields and thermal pressure observed at ACE/Wind;
- Note that the model is determined from STEREO B data only, and ACE/Wind are well separated from STEREO B;
- Justify that the thermal pressure and axial field are functions of *A* alone;
- Reinforce the idea of the flux-rope geometry!



Overall configuration



- Similar axis orientation at 4 spacecraft: $\theta \sim 50^{0}, \varphi \sim 270^{0}$;
- Right-handed at each spacecraft;
- STEREO B crossed the axis;
- ACE/Wind and STEREO A crossed the flank;
- Radial width is similar at STEREO B and